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Selection of Controller Structure

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9-1 INTRODUCTION

In working with control system design for a multivariable process the terms control strategy, control structure, and controller structure are sometimes used interchangeably. They then mean the selection and pairing of controlled and manipulative variables to form a complete, functional control system. However, the three terms can also be taken to have their own individual meaning. In this case control strategy describes how the main loops in a process are to be set up in order to meet the overall objectives. For example, if the objective of a column is to produce a bottoms product stream, the control strategy to insure the purity of the product might be to use reboiler heat to keep the impurities out. Control structure, on the other hand, is the selection of controlled and manipulated variables from a set of many choices. For example, the choice of reflux flow and reboiler heat (R-V) to control both distillate and bottoms compositions in a column gives one possible control structure. Alternatively using distillate flow and reboiler heat (D-V) gives another control structure. Controller structure finally means the specific pairing of the controlled and manipulative variables by way of feedback controllers. For example, a controller structure that specifies reflux flow to control distillate composition and reboiler heat to control bottoms composition is possible in an R-V control structure.

The title of this chapter is selection of controller structure. However, I am not going to stick to the fairly narrow interpretation given above. Instead I will describe a methodology for designing a multivariable control system that includes elements of control strategy considerations, control structure selection, and variable pairing.

This methodology is largely empirical based on general principles for distillation control such as those outlined in Chapter 1. However, the methods presented here fit well into more formal approaches for selecting and tuning control structures as described in Chapters 8, 10, and 11.

The methodology for control system design I will present assumes that the process is fixed and process changes are not permitted in order to come up with the final control scheme. Although this assumption could severely limit the possibilities for effective control (Downs and Doss, 1991) it is realistic in practice because control engineers are often asked to design the control system for existing process configurations. It could either be for an existing plant or for a
new one well into the design phase. The process equipment including buffer tanks and control valves are then already designated and the task is to select the appropriate variables to be controlled and design controllers that will tie the controlled variables to the control valves in such a way that the resulting controller structure meets the desired objectives.

I will also assume that the final controller structure will be built up around conventional control elements such as PID controllers, ratio, feedforward, and override control blocks as found in all commercial distributed control systems. I will not address the design of multivariable controllers such as DMC, which is treated in Chapter 12.

9-1-1 Control Design Principles

The process control field is characterized by algorithms and mathematical procedures for analysis, design, and control; but if you are looking for another algorithm for selection of controller structures you will not find it here. Not that I am against algorithms per se, I just happen to believe that they compete poorly against a combination of other activities in process control design, namely, definition of the control system objectives, process understanding and rigorous dynamic simulation. Others have expressed a similar view (Downs and Doss, 1991). Because these three activities are central to the design principles expressed in this chapter, I will say a few more words about each of them.

Defining and understanding the control system objectives should be a collaborative effort between process engineers, control engineers, and plant personnel. Left to any one of these contributors alone, the objectives can be severely biased. For example, a control engineer might be tempted to make the control system too complex in order for it to do more than is justified based on existing disturbances and possible yield and energy savings, whereas a process engineer might underestimate what process control can achieve and thus make the objectives less demanding. It is crucial to define what the control system should do as well as to understand what disturbances it has to deal with.

Process understanding is another key activity for successful control system design. Nobody seems to disagree with this notion, but in practice more time is usually spent on designing and implementing algorithms and complex controllers than on analyzing process data and figuring out how the process really works. Modelling and simulation are key parts in the process understanding step.

Rigorous dynamic simulation is the third important activity in control system design. A flexible dynamic simulation tool allows rapid evaluation of different control structures and their response to various disturbances. The attributes of a dynamic simulator ideal for control system work are outlined in Chapter 5.

The methodology I advocate for controller structure selection is the following:

- Define the objectives of the control system and the nature of the disturbances.
- Understand the principles of the process in terms of its dynamic behavior.
- Propose a control structure consistent with the objectives and the process characteristics.
- Assign controllers and evaluate through simulation the proposed control structure with the anticipated disturbances.

Before we embark on the details of this methodology it will be useful to first examine the nature and roles of the manipulative variables that will be used by the controllers in the proposed control structures.

9-2 MANIPULATIVE VARIABLES

When a process engineer works with a flowsheet or a detailed steady-state simulation of a distillation column a certain number of variables have to be specified or “controlled” in order to get a solution. For example, for a two-product column two specifications have to be given (e.g., product